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UTILIZATION OF AN/APS-94 SIDE-LOOKING AIRBORNE RADAR SYSTEMS IN--ETC(U)
APR 82 S R OSMER, L NASH, G L HOVER DTCG39-81-C-80287

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This report is the eighth in a series which documents the Probability of Detection Task of the SAR project at the U.S.C.G. R&D Center.

16. Abstract

Since September 1978, side-looking airborne radar (SLAR) detection data have been gathered in conjunction with visual detection experiments conducted by the U.S.C.G. R&D Center. These are part of a series of experiments designed to improve search planning guidance contained in the National Search and Rescue Manual.

HC-130 aircraft, equipped with either the Airborne Oil Surveillance System (AOSS) or SLAR/radar image processor (SLAR/RIP) configuration of the AN/APS-94C or D SLAR, conducted controlled searches for life rafts, small boats, and 41- to 95-foot Coast Guard vessels.

Through the use of a microwave tracking system and SLAR data, the positions of searchers and targets were accurately reconstructed to facilitate the verification of detections on SLAR films or video tape. These data were used to evaluate the effects of environmental and controllable parameters on SLAR detection of the various target types.

Of the 12 parameters investigated, target size/composition, search altitude, swell height, wind speed, and humidity/precipitation were found to have a significant influence on SLAR detection performance. Sweep widths for SLAR search and recommendations for SLAR utilization in SAR missions are included. In addition, recommendations for future SLAR evaluation are made.

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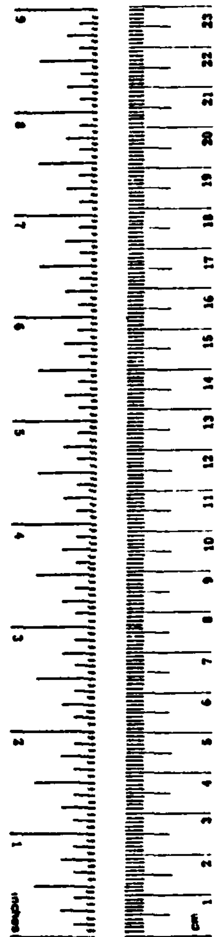
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

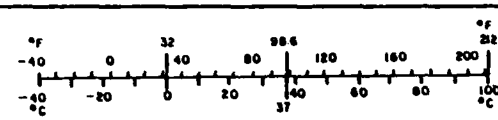
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Chapter 1
INTRODUCTION

1.1 PURPOSE OF REPORT

The interim report, Evaluation of Two AN/APS-94 Side-Looking Airborne Radar Systems in the Detection of Search and Rescue Targets (Reference 1), was published by the Coast Guard Research and Development Center as part of the electronic search evaluation task of the Probability of Detection (POD) in Search and Rescue (SAR) Project. The interim report presented all side-looking airborne radar (SLAR) data collected during the Project along with analysis results, conclusions, recommendations for the employment of SLAR in the SAR and enforcement-of-laws-and-treaties (ELT) missions, and recommendations for future testing. A complete assessment of the real-time, operational search capabilities of the AN/APS-94 SLARs was not possible because the sensor was available for only a small fraction of the planned experiment days during 1978 through 1981.

Since publication of the August 1981 SLAR report, one additional electronic detection experiment (fall 1981) has been conducted as part of the POD in SAR Project. One of the objectives of the fall 1981 experiment (Reference 2) was to collect SLAR data in accordance with recommendations made in the interim report. Unfortunately, due to unexpectedly extensive maintenance/overhaul of the CG 1347 Airborne Oil Surveillance System (AOSS) aircraft, the SLAR portion of the experiment had to be cancelled.

Because no additional SLAR detection data have been collected since publication of the August 1981 report, this report will review and expand the conclusions and recommendations made previously. This report will attempt to provide an assessment of SLAR utilization and effectiveness in SAR operations. The reader is referred to Reference 1 for a complete description of the SLAR experiments, data analysis, and experiment results.

1.2 BACKGROUND

While SLAR has been used aboard HC-130B aircraft primarily for airborne surveillance of oil spills and icebergs, it has potential for use as a SAR sensor because of its superior resolution and detection range compared to standard search radars and because of its image-processing capabilities. In situations where other methods of search are ineffective or impossible, SLAR, which is not as susceptible to adverse environmental conditions, may provide a means of detecting SAR targets. SLAR also has the capability to search a very large area in a short period of time, making it a valuable sensor in time-critical situations.

To evaluate the effectiveness of SLAR for the Coast Guard SAR mission, SLAR searches were conducted in conjunction with three visual detection experiments in Block Island Sound during fall 1978, fall 1979, and spring 1980. In addition, SLAR searches were conducted on three days during a January 1979 leeway drift experiment off the Florida coast. SLAR systems were not available for testing during the spring 1979, fall 1980, winter 1981, and fall 1981 detection experiments. Availability of SLAR systems for testing has been a problem throughout the test period.

Analysis of the collected data has been conducted to determine the influence that certain environment-related and controllable parameters have on SLAR detection of the target types described above. Parameters that were investigated over a limited range of values are:

Environment-Related	Controllable
Wind speed	Target size and composition
Swell height	Antenna polarization
Relative humidity	Gain (SLAR/RIP only)
Precipitation	Altitude
Image background	Lateral range
Visibility	Relative wave direction

1.3 DESCRIPTION OF SLAR

The SLAR units tested during the experiments are the AOSS and SLAR/Radar Image Processor (RIP) system. Both of these units are versions of the AN/APS-94C or D real aperture radar system interfaced with an onboard computer system, television monitors, and photographic and videotape recorders.

The AOSS SLAR employs two permanent side-mounted antennae: an 8-foot vertically polarized antenna on the right and a 16-foot horizontally polarized antenna on the left fuselage of the CG 1347 HC-130B aircraft. The vertically polarized antenna has been found to be effective in detecting changes in sea return (such as those caused by oil spills), while the horizontally polarized antenna has proven more efficient at detecting "hard" targets such as ships and icebergs. The SLAR/RIP system employs a single, 16-foot long removable antenna mounted below the tail of the CG 1351 HC-130B aircraft, and is equipped with a RIP which performs sophisticated image analysis and storage/retrieval functions. The reader is referred to References 3 and 4 for complete descriptions of the two SLAR systems.

Chapter 2
RESULTS AND CONCLUSIONS

Because target positions were known and all data were generated via post-experiment analysis of the SLAR imagery, results presented in this report represent an upper bound on present SLAR detection capabilities. Thus, lateral range curves and sweep widths included in this report should be used only with caution to predict real-time, operational search performance.

Parameters that were found to have a significant influence on the detectability of SAR targets under the good to moderate conditions encountered during these experiments include:

<u>Environment-Related</u>	<u>Controllable</u>
Swell height	Target size and composition
Wind speed	Lateral range
Visibility	Altitude
Precipitation	Gain (SLAR/RIP only)
Relative humidity	

Lateral range curves were fitted to the experiment data collected at the optimum search altitude for each SLAR type/target combination tested (Reference 1). Sweep width estimates based upon these lateral range curves are presented in Table 2-1.

The influence on SLAR detection performance of parameters other than target type and lateral range was discernible only with small boat and raft targets. Detection of 41- to 95-foot metal-hulled Coast Guard boats was excellent under all conditions tested, and fell below 90+ percent only beyond ranges greater than about two-thirds of maximum sensor range. Consequently, other parameters demonstrated no significant influence on detection probability with these targets over the range of conditions encountered. The following conclusions refer to detection of small boats and life rafts:

Table 2-1. Half Sweep Width Estimates with 90-Percent Confidence Limits for SLAR Searches at Optimum Search Altitudes

SLAR Type	Target Type	Half Sweep Widths[1] Lower 90 Percent Confidence Limit (nm)	Estimate (nm)	Upper 90 Percent Confidence Limit (nm)	Optimum Search Altitudes (ft)
AOSS SLAR	41'-95' Coast Guard Vessels	22.0	23.6	24.9	None determined[2]
	13'-18' Fiberglass Boats without Equipment	6.5	8.0	9.6	2000
	16'-21' Fiberglass or Aluminum Boats with Equipment	8.6	10.4	12.3	2000
	4-6 Man Canopied Life Rafts without Radar Reflectors	5.2	6.3	7.6	2000-3000
	7-Man Non-Canopied Life Raft without Radar Reflector	5.2	6.3	7.6	2000-3000
SLAR/RIP	41'-95' Coast Guard Vessels	38.5	40.8	42.6	None determined[3]
	13'-18' Fiberglass Boats without Equipment	9.7	10.6	11.5	2000-3000
	16'-21' Fiberglass or Aluminum Boats with Equipment	15.7	16.9	18.2	2000-3000
	4-6 Man Canopied Life Rafts without Radar Reflectors	8.1	9.0	10.1	2000-3000
	7-Man Canopied Life Raft without Radar Reflector	10.3	12.0	13.9	2000-3000

[1]In Reference 1, Executive Summary Table 2 and Table 3-7 in Chapter 3 were incorrectly labelled. The heading "Sweep Widths" should read "Half Sweep Widths"; that is, the tables contain sweep widths to one side of the aircraft.

[2]Data collected at altitudes from 1000 to 5000 feet.

[3]Data collected at altitudes from 1000 to 7500 feet.

1. Swell Height. Swell heights less that 1.5 feet generally yielded better detection performance than swell heights from 2.0 to 4.0 feet. This performance difference was only statistically significant, however, for AOSS SLAR searching for rafts.

2. Wind Speed. Wind speeds less than 10 knots resulted in better performance than wind speeds of 11 to 30 knots; however, this difference was only significant for SLAR/RIP searching for life rafts.

3. Visibility/Precipitation/Relative Humidity. These three parameters, which are related to atmospheric interference with microwave signal propagation, all demonstrated negative effects on detection performance with one or more SLAR type/target type combinations.

4. Target Size and Composition. This parameter, which relates to target radar cross-section, is by far the most influential in determining target detection performance. Small rubber rafts and fiberglass boats without engines were detected less frequently than engine-equipped 16- to 21-foot boats at all lateral ranges. Sweep widths given in Table 2-1 reflect this difference in detectability.

5. Search Altitude. Search altitudes of 2000- to 3000-feet were generally found to yield optimum small-target detection performance for both SLAR systems.

6. Gain (SLAR/RIP only). Tests indicated that higher gain settings than those typically used by SLAR/RIP operators at a given altitude may yield improved small-target detection performance.

Chapter 3
RECOMMENDATIONS FOR USE OF SLAR AS A SAR SENSOR

3.1 INTRODUCTION

Analysis of the SLAR data presented in Reference 1 showed that the Coast Guard AOSS and National Aeronautics and Space Administration (NASA) RIP configurations of the AN/APS-94 SLAR were capable of detecting targets as small as fiberglass pleasure boats under 20-feet long and 4- to 7-man life rafts under good to moderate environmental conditions. On the basis of these results, it is appropriate to address where, when, and how SLAR snould be employed in the SAR mission.

At present, the AOSS SLAR is the only operational system in the Coast Guard. The SLAR/RIP system was a prototype and is no longer available. The new AN/APS-131 and -135 SLARs are not yet in the field and have yet to be evaluated. Therefore, this chapter addresses employment of the AOSS system only.

3.2 SEARCH AREAS AND MISSION TYPES

SLAR is a wide-area sensor and is not selective of specific target types and colors the way a human lookout can be. These qualities must be taken into consideration when choosing how and when to employ SLAR in the SAR mission. The following recommendations are based upon experiment results.

- o SLAR should ordinarily be used only in search areas with low traffic density.
- o SLAR should be employed in SAR missions involving large search areas where target position is very uncertain.
- o SLAR may be the only sensor available in weather conditions that prevent effective visual search because of darkness, fog, precipitation,

or high sea/swell state. Under these circumstances in time-critical situations, it may be beneficial to use SLAR even where traffic density is normally high.

3.3 TARGET TYPES

3.3.1 Medium Targets

Experiment data show that, under moderate to excellent weather conditions, metal-hulled vessels longer than 40 feet are detected nearly 100 percent of the time. In this case, SLAR can be considered a definite detection law sensor with its minimum detection range from the flight track being a distance approximately equal to aircraft altitude and maximum detection range being about 27 nm for AOSS SLAR. Since some degradation of detection performance was noted in the outer third of each sensor's range capability, search track spacing should be chosen so that this portion of the SLAR lateral range curve overlaps on successive search legs. Figure 3-1 illustrates this method. If conditions permit, visual scanners should be used to compensate for the blind zone that exists under the aircraft due to the angle at which the SLAR microwave signal is transmitted. Scanners should concentrate on the area directly ahead of the aircraft and to each side a distance slightly greater than the search altitude. When conditions do not permit visual search to compensate for the blind zone, a second SLAR search should be conducted with tracklines offset from those of the first search a distance approximately equal to one third the maximum detection range.

With medium to large metal-hulled targets, a POD of nearly 100 percent should be achievable in good weather if the methods described above are used and the aircraft is able to execute its search pattern precisely.

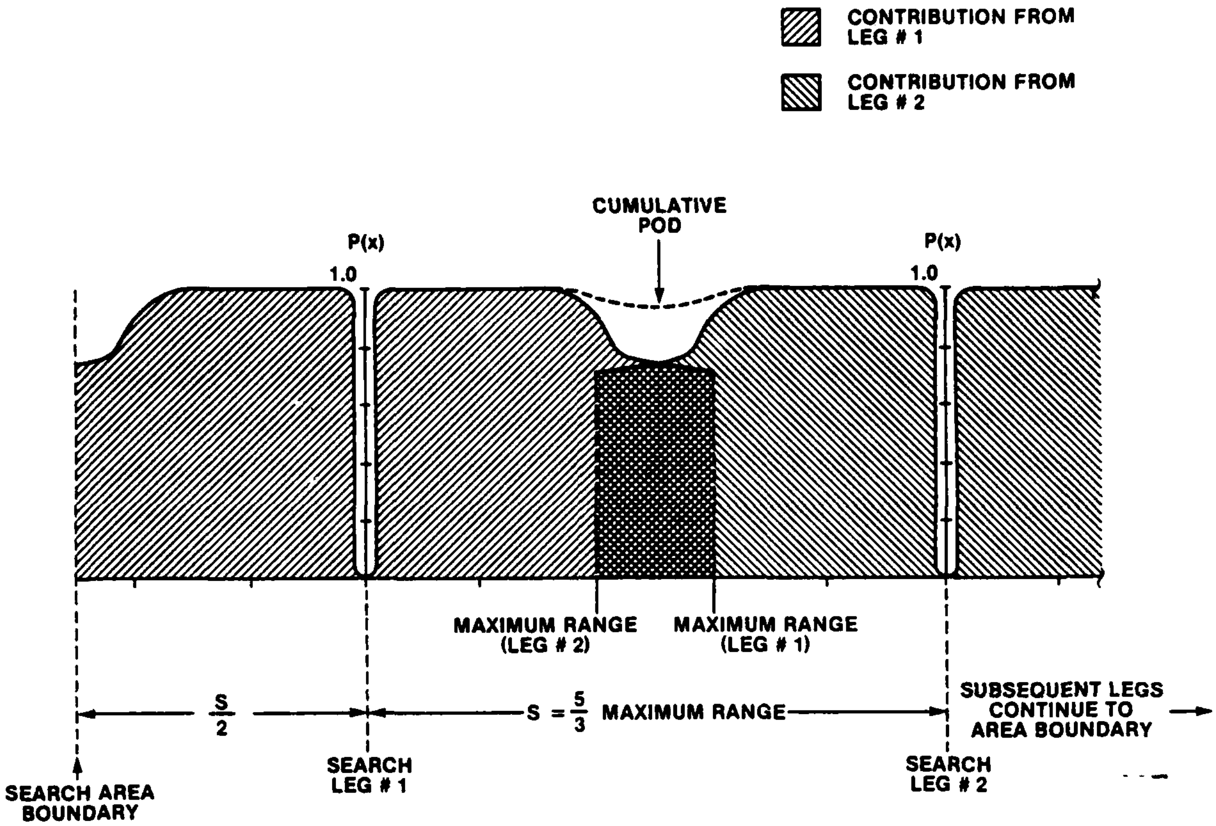

Figure 3-1. Example of Search Area Coverage: SLAR Searching for 41- to 95-foot Metal-Hulled Boats

3.3.2 Small Boats and Life Rafts

Optimizing SLAR usage presents a more complex problem when searching for small targets. The target detection probability versus lateral range curve no longer reflects a definite detection capability but is unimodal (see Figure 3-2) with maximum detection probabilities that can range from 0 to nearly 1. The variable shapes of these lateral range curves make it difficult to determine what track spacing (S) should be used to attain a desired cumulative probability of detection (POD) for the search. Unlike visual search,

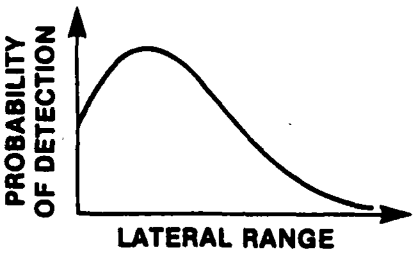

Figure 3-2. Unimodal Lateral Range Curve

where sweep width (W) is used to assign track spacing for a desired POD based upon the inverse-cube detection law (see Reference 5), SLAR searches must be planned to compensate for the blind zone and to achieve fairly uniform detection probability throughout the search area. As with larger targets, visual scanners should be used to fill in the blind zone when conditions permit. Figure 3-3 illustrates combined SLAR/visual search lateral range curves.

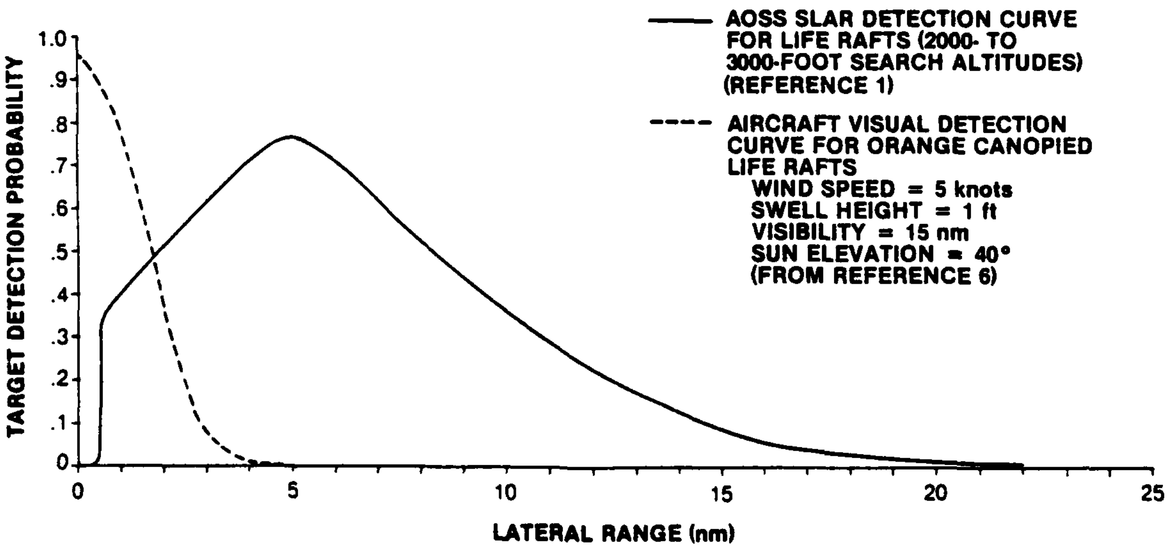

Figure 3-3. Example of Combined AOSS SLAR and Visual Lateral Range Curves (canopied life raft target, good conditions)

Figure 3-4 illustrates an example of the area coverage that would be attainable with AOSS SLAR alone searching for life rafts based upon experiment results (Reference 1). The 20-nm track spacing results in virtually no filling-in of the blind zone, but provides a reasonably narrow range (.56 to .77) of detection probabilities between tracks. A subsequent search of the area, offset about one-fourth track spacing from the initial search, should be conducted to fill in the areas left unsearched due to the blind zone and smooth the "dip" in POD that occurs midway between tracks. Cumulative POD will increase throughout the search area with each subsequent search.

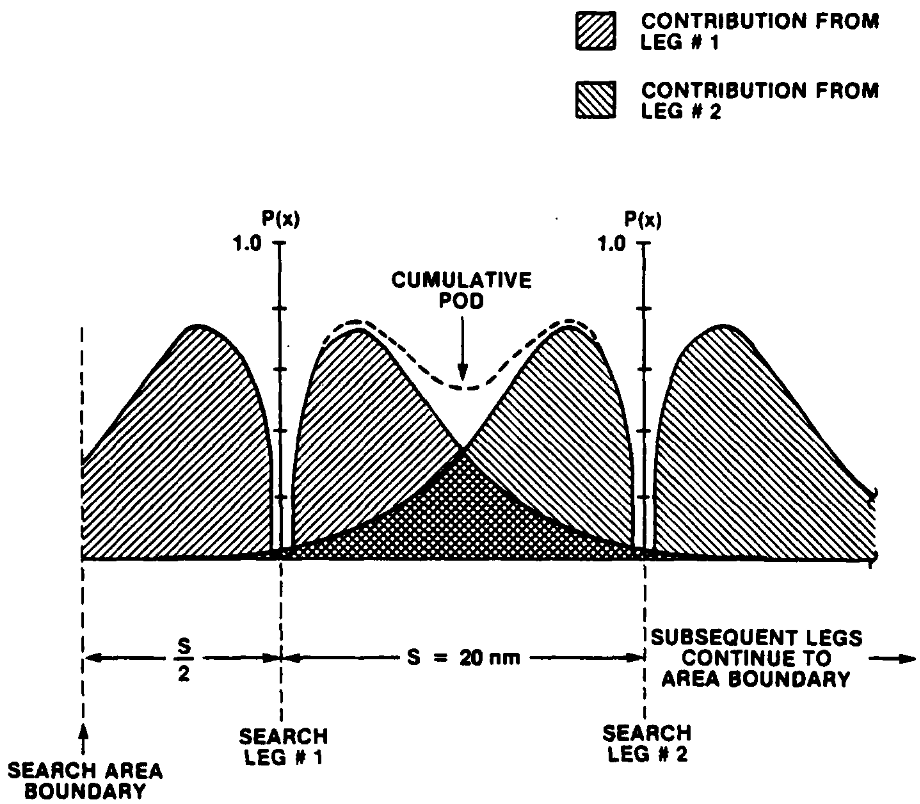

Figure 3-4. Example of Search Area Coverage: AOSS SLAR Searching for Life Rafts (2000- to 3000-foot search altitudes)

3.4 SLAR SEARCH PLANNING

3.4.1 Track Spacing and Search Altitude Determination

It is difficult to determine by inspection exactly the track spacing that will yield uniform area coverage while attaining the highest possible POD for a given amount of SLAR time. Each unique combination of target type, SLAR type, and environmental conditions will be represented by a somewhat different lateral range curve. Thus, track spacing should be determined from the shape of the lateral range curve that applies to the existing search scenario.

For the AOSS SLAR used to search for a hard target approximately 40 feet long or longer, a recommended track spacing would be 45 nm based upon Figure 3-1 (5/3 of the AOSS 27-nm maximum detection range). Using this track spacing, the AOSS SLAR should cover the intended search area with a POD of nearly 100 percent. Table 2-1 indicates that all search altitudes tested (1000 to 5000 feet) yield similar detection performance.

For smaller targets, a recommended track spacing would be 20 nm under good environmental conditions. This estimate is a compromise among the various small-target lateral range curves calculated from experiment data. The search pattern recommended in Section 3.3.2 and an altitude between 2000 and 3000 feet will provide the best search area coverage. For a discussion of the suggested lateral range curves and search altitudes generated from experiment data, the reader is referred to Reference 1, Chapter 3.

3.4.2 POD Prediction

Assuming that supplementary visual search is possible to fill in the blind zone, the SLAR search planning method described in Section 3.4.1 should yield approximately the following single-search PODs:

Large targets (good weather)	90 to 100 percent
Small targets (good weather)	50 to 70 percent*

The Coast Guard's Computer-Assisted Search Planning (CASP) model (Reference 7), which computes POD by "driving" a lateral range curve through a simulated search, would be an effective means of determining desired track spacing and predicting POD for any particular SLAR search. By using an iterative approach, CASP should be able to determine the track spacing that would result in the highest cumulative POD and most uniform search area coverage for a given amount of time. Any future manual SLAR search planning method should depend upon tabulated data from CASP runs using empirically derived lateral range curves, which represent a full range of target types and environmental conditions.

*Within the search area, POD will vary over this range of values in relation to distance from the aircraft track.

Chapter 4
RECOMMENDATIONS FOR FUTURE WORK

The following recommendations are made for future research, development, testing, and evaluation of SLAR for Coast Guard missions:

1. Test larger (25- to 50-man) life rafts and life boat targets of the type one would expect in an open-ocean SAR mission involving airplane or cruise ship mishaps.

2. Evaluate SLAR detection capability for medium and large targets under more severe environmental conditions and a greater range of search altitudes.

3. Conduct tests of new Coast Guard SLARs (that is, the AN/APS-131 and AN/APS-135) in two phases:

   a. A system performance evaluation based upon post-experiment reconstruction to identify significant parameters and

   b. Evaluation of real-time, operational detection capability in an open-ocean search scenario.

4. Develop lateral range curves that represent the real-time, operational detection capability of present and planned Coast Guard SLAR systems for an appropriate range of target types and environmental conditions. The curves should be provided as inputs to the CASP model.

5. Ensure that SLAR operators are expertly trained in the alignment and operation of their SLAR equipment and in making optimum use of all available image processing capabilities such as those planned for the AIREYE multifunction display (Reference 8). Operators should

also be able to spot and classify common SAR targets in real time on their video monitors and film displays.

6. In future radar image processors, include state-of-the-art algorithms that facilitate automatic recognition, classification, and tracking of as wide a variety of SAR targets as is technologically feasible.

7. Guidance on SLAR searches and utilization should be included in the National SAR Manual (Reference 9).

REFERENCES

1. Osmer, S. R.; Edwards, N. C.; Hover, G. L.; and Mazour, T. J. Evaluation of Two AN/APS-94 Side-Looking Airborne Radar Systems in the Detection of Search and Rescue Targets. Report No. CG-D-64-81. USCG Research and Development Center and Analysis & Technology, Inc. August 1981.

2. USCG R&D Center. Fall 1981 Radar/FLIR/SLAR Detection Experiment Test Plan. 10 August 1981.

3. Vollmers, R. R.; Muehlenbeck, C.; and Wiley, L. Airborne Oil Spill Detection and Tracking System. USCG paper. October 1977.

4. Marthaler, J. G., and Heighway, J. E. "Radar Image Processing of Real Aperture SLAR Data for the Detection and Identification of Iceberg and Ship Targets." Fifth Canadian Symposium on Remote Sensing. Victoria, B. C. August 1978.

5. Koopman, B. O. Search and Screening. U. S. Navy OEG Report No. 56. Washington, D.C. 1946.

6. Edwards, N. C.; Osmer, S. R.; Mazour, T. J.; and Hover, G. L. Analysis of Visual Detection Performance for 16-Foot Boat and Life Raft Targets. Report No. CG-D-24-80. USCG Research and Development Center and Analysis & Technology, Inc. February 1980.

7. Computerized Search and Rescue Handbook. U. S. Coast Guard. 1 January 1974.

8. White, J. R., and Schmidt, R. E. AIREYE: A New Generation Oil Pollution Sensing System for the '80s. U. S. Coast Guard. Washington, D. C.

9. USCG. _National Search and Rescue Manual_. USCG COMDTINST M16130.2, Superintendent of Documents. Washington, D. C.: Government Printing Office, July 1973.


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